



THE IMPACT OF ONLINE EDUCATION ON STUDENTS' KNOWLEDGE OF HUMAN EVOLUTION

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Introduction

During the 2019/20 and 2020/21 school years, schooling unexpectedly and abruptly shifted from in-class education to online education due to the COVID-19 pandemic. Across the world, 94% of students were affected (Crompton et al., 2021). The lockdown influenced all aspects of society: the economy, human relations, and mental health. It found teachers and students ill prepared for this situation. Online platforms became the main teaching and learning tool at all levels of education, along with Moodle or similar learning management systems. Schrum and Hong (2002, p. 57) suggested the following seven dimensions that are important for students' success at online learning: "access to tools, technology experience, learning preferences, study habits and skills, goals or purposes, lifestyle factors, and personal traits and characteristics." Andrew et al. (2020) found that students' experiences during the lockdown varied. An important disadvantage was the lack of suitable infrastructure at home. This was one of the reasons that students and parents reported reduced motivation to participate in online education and felt that such education was less effective (Almendingen et al., 2021; Coman et al., 2020; Hornstra et al., 2022; Steyn et al., 2023). Also reported were lower attendance, participation, and engagement (Steyn et al., 2023). Students' satisfaction with distance learning was found to be diminished in some studies (McWatt, 2021), but Martinez (2022) found that students preferred online teaching to in-class teaching. Notable risk factors for students were social isolation and loneliness (Almendingen et al., 2021; Dayal, 2023; McWatt, 2021; Postigo-Zegarra et al., 2021). However, online learning also contributed to more communication among students (Brunelli & Macirella, 2021; Zhang, J. et al., 2022).

During the lockdown, students' personal circumstances related to their situation before the pandemic were also exacerbated (Bosch et al., 2022; Dayal, 2023). They faced various physical (e.g., neck pain and headache) and mental issues (e.g., stress and anxiety; Dayal, 2023). Among students that were most negatively influenced by distance learning were deprived groups and low achievers (da Silva Oliveira et al., 2022; Fiedler et al., 2022). In contrast, high achievers and those with high self-efficacy and self-organization abilities were less negatively influenced (Samsen-Bronsveld et al., 2023; Zhang et al., 2021).

Abstract. *In the 2020/21 school year, education changed overnight due to the COVID-19 pandemic. The aim of this study was to explore the impact of the lockdown on students' knowledge of evolution. Two student groups were compared; both covered the same subject matter, and only the implementation differed: either online or in class. The sample consisted of 476 participants, 15 to 16 years old. Data were collected with a questionnaire using a 5-point Likert scale. Contrary to expectations, there were no significant differences in knowledge between the online and in-class groups. The reasons for this remain unclear. The impact of some contextual factors was also tested. There were no significant differences in students' performance concerning maternal education, and only two concerning paternal education. Males scored better than females. Knowledge of human evolution did not correlate with religiosity. However, it did correlate with acceptance of evolution and attitudes toward biology. The online educated group and the in-school educated group differed significantly in most correlations between contextual factors. Further studies should be carried out on students that experienced the lockdown to better understand its consequences, especially if these are long lasting.*

Keywords: COVID-19 pandemic, evolution acceptance, attitudes toward biology, students' religiosity, parents' education, students' gender

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The research found predominantly reduced academic achievement among students during the lockdown (Almendigen et al., 2021; Spitzer et al., 2023; Wang et al., 2022), and some studies found a positive influence (Spitzer et al., 2023); however, McWatt (2021) found no differences in achievements before and after the lockdown. This was due to active learning methods that promote critical thinking (Poulain et al., 2021; Rossi et al., 2021). Motivation and achievements during online classes seemed to be positively affected by more relaxed, informal relationships between students and teachers because they were all intruding into one another's private lives (Brunelli & Macirella, 2021; McDavid et al., 2020; Salmi et al., 2023).

During the lockdown, schools were inclined to be more patient and lenient with students, and standards were often lowered (Barton, 2023). A survey in the United States showed that primary and secondary school students were several months behind schedule due to the pandemic. This effect could possibly be visible in the schools at higher levels of education in the following years when these students enter them (Dorn et al., 2021; Steyn et al., 2023).

The teachers, too, were caught in this challenging situation and found it difficult to prepare online classes (Dayal, 2023; Sorakin et al., 2022). Teachers stressed a lack of teaching skills for distance teaching and also poor knowledge of the technology needed (Yu, 2022). Bertoletti et al. (2023) reported that one-third of the teachers did not use digital technology for teaching because they did not feel comfortable using it. However, those that did use it reported higher levels of satisfaction with their work and higher achievements by students.

Digital literacy, the most important prerequisite for successful distance learning and teaching, improved during the lockdown but still needs improvement (Yu, 2022). It is expected that digital knowledge and the skills gained, as well as the materials prepared during the lockdown, have been integrated into regular in-school classes (Barton, 2023).

Research Problem

Research indicates both positive and negative effects of online education. The COVID-19 pandemic presented a rare opportunity to explore this in a real situation and not in an experimental setting. For this reason, in this study one group consisted of students from the cohort that took part in online education. Online education applied for these students from October 19th, 2020, to February 12th, 2021, and from April 1st to April 9th, 2021, in a school year that lasted from the beginning of September 2020 to June 24th, 2021. The choice of human evolution was guided by the fact that, according to the Slovenian national curriculum (Učni načrt, 2011), it is 1) relatively independent and separate subject matter that 2) students first familiarize themselves with in greater detail at age 14 to 15. Two student groups were compared; both covered the same subject matter, and only the implementation differed (online or in class).

Research concerning evolution focuses on understanding evolutionary concepts and acceptance of evolutionary theory (Bajd, 2012). The correlation between understanding evolution and acceptance of evolution is inconsistent; some have found a positive relationship (e.g., Belin & Kisida, 2015; Beniermann, 2019; Carter et al., 2015; Kuschmierz et al., 2021; Mead et al., 2017; Salazar-Enriquez et al., 2023; Tavares & Bobrowski, 2018), but others have found no relationship (e.g., Beniermann, 2019; Kuschmierz et al., 2020).

Additional factors influencing acceptance of evolution are students' gender and religiosity. Females' acceptance of evolution is mostly lower, but this could be a consequence of religiosity, which is generally higher in females (Fiedler et al., 2024; Stahi-Hitin & Yarden, 2022). Less is known about how understanding evolutionary concepts and acceptance of evolutionary theory is influenced by different school settings (Kuschmierz et al., 2020). It has been suggested that the amount of teaching positively affects acceptance of evolution and understanding evolution (Grossman & Fleet, 2017; Mantelas & Mavrikaki, 2020; Mead et al., 2017).

To measure the impact of online education, a study of this type of education in real situations is valuable. This study sought to identify how students' knowledge of human evolution was impacted by online education. It was assumed that students engaged in in-class learning would show higher academic achievements than students learning online (Fiedler et al., 2022).

Research Focus

This study explored whether online education impacted students' knowledge of human evolution. The first objective was to conduct a survey to gather data on knowledge of human evolution among students that were exposed to online education during the COVID-19 pandemic and those that had learned about human evolution through in-class education. The second objective was to explore the possible impact of gender and parental edu-



cation on knowledge of human evolution. The third objective was to gather data on contextual factors (religiosity, attitudes toward biology, and acceptance of evolutionary concepts). The fourth objective was to explore possible correlations between knowledge of human evolution and contextual factors in the online and in-class groups. The fifth objective was to draw conclusions and make recommendations based on this analysis. Accordingly, the following research questions were addressed:

RQ1: Was students' knowledge of human evolution impacted by online education?

RQ2: Was knowledge of human evolution impacted by students' gender and the level of parents' education?

RQ3: Was there a correlation between students' knowledge and acceptance of evolutionary concepts, their attitudes toward biology, and religiosity?

Research Methodology

General Background

The research design was quantitative and quasi-experimental. The research strategy was a survey. Data were collected using a questionnaire consisting of 59 items that was administered during regular biology classes. The answers to 14 items about knowledge of human evolution were used for quantitative analysis of students' knowledge of human evolution and the impact of online education on that knowledge. In addition, the impact of gender and parental education on knowledge was analyzed. The answers to the remaining 45 items were subjected to principal component analysis, which showed four components (religiosity, attitudes toward biology, acceptance of evolution: the theory, and acceptance of evolution: the theory is (not) scientific). The correlations between these four components, and between these four components and knowledge of evolution, were then calculated. The possible impact of online education on these correlations was also analyzed.

The study was conducted in the spring of the 2021/22 and 2022/23 school years. The participants were students attending upper-secondary schools. Most students from these schools continue their education at a university. One group learned about human evolution online during the COVID-19 pandemic, whereas the other group learned about it in class after the pandemic.

Consent was obtained from the students' parents or their guardians. Participation in the study was voluntary and anonymous, and no benefits were offered to the students. According to Slovenian legislation, such a survey does not need the approval of an ethics committee or similar body.

Participants

The total number of participants was 476, all 15 to 16 years old and attending four upper-secondary schools located in a city with a population of about 300,000. The population of students attending these schools was predominantly urban. Schools in that city were chosen because the pool of schools of a similar academic level is the highest there. In 2021/22, 1,183 students attended this type of school in that city (Černoša & Rački, 2023). Among the six schools that were originally chosen, only four agreed to participate. The power analysis (Mann-Whitney U test) indicated that a minimum total sample size to yield a statistical power of at least .95 with an alpha of .05 and an effect size of 0.5 for two groups was 244. The sample included 55.5% female and 43.3% male participants (Table 1). The percentage of each gender in the group educated online in comparison to the group educated in-class was not significantly different ($U = 25534.000$, $Z = -1.311$, $p = .190$).

In line with the Slovenian biology curriculum (Učni načrt, 2011), all students had learned about human evolution at age 14 to 15. The data were collected at one point in time for each group. The first group of students ($n = 247$), those that were surveyed in 2021/22, learned about evolution in the previous school year (2020/21), in which most education was carried out via online education during the lockdown due to the COVID-19 pandemic. Data for the second group of students, ($n = 229$) were collected in 2022/23. These students learned about evolution in the previous year (2021/22) when, after the pandemic, education resumed in schools (Table 1).



Table 1*Description of the Participants*

Demographic composition of the student sample		N	f (%)
Age	15–16 years	476	100
	Female	264	55.5
Gender	Male	206	43.3
	Missing data	6	1.3
Type of education	Online (2020/21)	247	51.9
	In-class (2021/22)	229	48.1
Data collected in year	2021/22	247	51.9
	2022/23	229	48.1

Instrument and Procedures

The questionnaire consisted of demographic questions (gender, educational level of both parents) followed by 14 items that tested students' knowledge of human evolution and 45 items about students' religiosity, attitudes toward biology, and acceptance of evolution. The 14 items that tested students' knowledge of human evolution were partly adapted from the study by Miller et al. (2006) and partly designed in line with the curriculum and the textbooks that the participants in this study used when learning about human evolution. The face validity of these 14 statements was ensured by the authors and the three biology teachers that judged and revised them. In addition, 10 items using the PERF scale (Beniermann, 2019) were applied to explore the religiosity of the participants. These items had already been translated into Slovenian and used by Torkar and Šorgo (2020) on a Slovenian sample. An additional eight items adapted from the Relevance of Science Education study (Sjøberg & Schreiner, 2019) explored students' attitudes toward biology. Another aspect monitored in this study was students' acceptance of evolution, which was tracked with 17 items taken from the MATE questionnaire (Rutledge & Sadler, 2007), and 10 items adapted from the questionnaire used by Miller et al. (2006). The questionnaire used a 5-point Likert scale for all 59 items, ranging from strongly disagree (= 1) to strongly agree (= 5). Eleven items were originally worded in such a way that disagreement was required as a correct answer; these items were recoded for statistical analysis. The questionnaire was administered during students' regular biology classes. Students completed the instrument in approximately 15 minutes. The part of the questionnaire that tested knowledge of human evolution (14 items) had relatively low reliability (Cronbach's $\alpha = .58$). However, the part of the questionnaire that tested students' religiosity, their attitudes toward biology, and acceptance of evolution (45 items) had high reliability (Cronbach's $\alpha = .82$).

Data Analysis

According to the Kolmogorov-Smirnov test of normality, the distributions of answers for all items were significantly non-normal ($ps < .001$). Therefore, non-parametric tests were used to explore differences 1) between the answers of students that had learned about human evolution online and those that had regular classes in school, 2) between females and males (Mann-Whitney test), and 3) between students with different parental education levels (Kruskal-Wallis test). The effect size r was calculated using the equations $r = Z / \sqrt{N}$ and $\epsilonpsilon\text{-squared} = H / (n^2 - 1) / (n + 1)$ (Tomczak & Tomczak, 2014).

Data were subjected to factor analysis by applying principal component analysis (PCA). The orthogonal rotation (varimax) method with Kaiser normalization was conducted on 45 items (Table S1). The value of the Kaiser-Meyer-Olkin measure of sampling adequacy was .932, which means that the sample size was adequate for PCA. Bartlett's test of sphericity was highly significant ($\chi^2 = 10751.494$, $df = 990$, $p < .001$), indicating that correlations between items were sufficiently large for PCA. According to PCA, four components could be extracted. Thirteen items were loaded onto component 1 (religiosity); 11 items were loaded onto component 2 (acceptance of evolution: the



theory); eight items were loaded onto component 3 (attitudes toward biology), and eight items were loaded onto component 4 (acceptance of evolution: the theory is (not) scientific). Five items were excluded because they were either loaded on two components or their loadings were too small. Cronbach's alphas for the four components were between .85 and .89. These four components explained 59.90% of the variance. Cronbach's alpha for all 40 items was .82. Additional results are available as supplementary material accompanying the online article.

Correlations between knowledge of human evolution, acceptance of evolution, religiosity, and attitudes toward biology were analyzed using Spearman's correlation coefficient (r_s). Comparisons of these correlations were then calculated to establish whether the differences between correlations of the two student groups were statistically significant. For this, the following equation was used: $Z_{\text{difference}} = (Zr_1 - Zr_2) / \sqrt{[1 / (N_1 - 3)] + [1 / (N_2 - 3)]}$ (Field, 2009, p. 191).

Research Results

Students' Knowledge of Human Evolution

On six items, the students performed above average ($M = 3.48$ – 4.56), and on the other eight items, their performance was average ($M = 2.58$ – 3.43 ; Table 2). There are no significant differences ($p > .05$; Table 2) in performance between the students that had learned about human evolution through online education during the lockdown in the 2021/22 school year ($M = 3.40$, $SD = 0.46$), and the following year of students that had learned about this topic in regular classes in school in the 2022/23 school year ($M = 3.39$, $SD = 0.41$). The effect sizes of differences in the online and in-class educated groups' answers are negligible ($.00 < r < .16$).

There are six significant differences in performance between females and males (Table S2). The effect sizes of these differences are mostly negligible ($.01 < r < .07$), and one is small ($r = .25$). For all six items, boys performed better than girls.

There are no significant differences in the students' performance concerning their mother's educational level ($ps > .05$). However, there are two significant differences in the students' performance concerning their father's educational level: item E4 (Neanderthals and modern humans share 99.7% of their genes; $p = .03$) and item rE38 (Modern humans did not live at the same time as dinosaurs; $p = .04$). In both cases, higher student achievements are associated with a higher level of paternal education. The effect sizes of differences are negligible ($.00 < r < .03$).

Table 2

Students' Knowledge of Human Evolution, Statistical Significance of Differences between the Online Group ($n = 229$) and the In-class Group ($n = 247$), and Effect Sizes of Differences

Statement	Type of education						Mann-Whitney U test		Effect size	
	All students ($N = 476$)		Online ($n = 247$)		In-class ($n = 229$)		U	Z	p	r
	M	SD	M	SD	M	SD				
rE38 Modern humans did not live at the same time as dinosaurs.*	4.56	0.821	4.58	0.820	4.54	0.823	26108.500	-0.693	.488	-.03
E3 Today, all human species are extinct, except for our species, modern humans.	3.95	1.142	3.92	1.144	3.99	1.141	26343.000	-0.724	.469	-.03
E41 Humans and chimpanzees evolved from a common ancestor.	3.74	1.029	3.74	1.062	3.74	1.062	27274.500	-0.224	.823	-.01
rE26 Humans today do not have more or less the same form as we have always had.*	3.67	1.060	3.64	1.079	3.70	1.040	26479.500	-0.539	.590	-.02
rE5 The common ancestor of humans and chimpanzees does not live in Africa anymore.*	3.57	1.119	3.58	1.123	3.57	1.116	27128.500	-0.148	.882	-.01
E37 Humans' three closest relatives in terms of evolutionary development are gorillas, orangutans, and chimpanzees.	3.48	1.003	3.54	0.963	3.42	1.043	25302.500	-1.150	.250	-.05



Statement	Type of education									
	All students (N = 476)		Online (n = 247)		In-class (n = 229)		Mann-Whitney U test			Effect size <i>r</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>U</i>	<i>Z</i>	<i>p</i>	
E34 Modern humans evolved in Africa.	3.43	0.992	3.43	1.021	3.43	0.964	27001.000	–0.345	.730	–.02
E19 Neanderthals lived in Europe, Asia, and the Middle East.	3.42	0.864	3.43	0.885	3.41	0.843	27371.500	–0.240	.810	–.01
rE35 Humans did not evolve from chimpanzees.*	3.42	1.191	3.36	1.196	3.49	1.185	26046.000	–1.156	.248	–.05
E4 Neanderthals and modern humans share 99.7% of their genes.	3.25	0.988	3.19	0.966	3.32	1.008	25188.500	–1.473	.141	–.07
rE33 Modern humans did not evolve less than 15,000 years ago.*	2.94	1.041	3.00	1.063	2.89	1.015	25396.500	–1.351	.177	–.06
E36 Modern humans and Neanderthals lived on Earth at the same time.	2.87	1.429	2.95	1.415	2.79	1.441	24841.500	–1.222	.222	–.06
rE1 Modern humans did not evolve from Neanderthals.*	2.69	1.346	2.77	1.406	2.60	1.276	26100.500	1.196	.232	–.06
E2 Modern humans lived at the same time as mammoths.	2.58	1.239	2.55	1.262	2.62	1.215	26555.000	–0.639	.523	–.03
Total	3.39	0.440	3.40	0.460	3.39	0.413	27607.500	–0.450	.653	–.02

*reversed statement

Correlations between Students' Knowledge of Human Evolution and Contextual Factors

Correlations between students' knowledge of human evolution and the four components that were extracted in PCA were calculated for the students that had learned about human evolution through online education (Table 3) and students that had learned about human evolution in class (Table 4). There are no statistically significant correlations among the four components in either group. However, there are correlations between knowledge of human evolution and some of the four components. In the online educated group, knowledge of human evolution correlates with components F2 (Acceptance of evolution: the theory), F3 (Attitudes toward biology), and F4 (Acceptance of evolution: the theory is (not) scientific). In the in-class educated group, knowledge of human evolution correlates with F2 (Acceptance of evolution: the theory) and F4 (Acceptance of evolution: the theory is (not) scientific). Four correlations are small ($.18 < r_s < .36$), and one is medium ($r_s = .40$).

A comparison of correlations between the online and in-class groups was calculated (Table 5). The correlations between knowledge of human evolution and the four components obtained in PCA in the group that had learned about human evolution online are mostly significantly different ($ps < .01$) from the correlations in the in-class group that had learned about human evolution in regular in-school classes. Only two correlations are similar in both groups: between attitudes toward biology (F3) and religiosity (F1; $p = .37$), and between attitudes toward biology (F3) and acceptance of evolution: the theory is (not) scientific (F4; $p = .28$).

Table 3

Correlations between Students' Knowledge of Human Evolution and Contextual Factors (Online Group)

Components obtained in PCA	Online education			
	F1	F2	F3	F4
F1 Religiosity	1.00			
F2 Acceptance of evolution: the theory	–.03	1.00		
F3 Attitudes toward biology	–.00	–.03	1.00	
F4 Acceptance of evolution: the theory is (not) scientific	.03	–.03	.01	1.00
Knowledge of human evolution	.01	.40**	.18*	.28**

* $p < .05$, ** $p < .01$ 

Table 4*Correlations between Students' Knowledge of Human Evolution and Contextual Factors (In-Class Group)*

Components obtained in PCA	In-class education			
	F1	F2	F3	F4
F1 Religiosity	1.00			
F2 Acceptance of evolution: the theory	.06	1.00		
F3 Attitudes toward biology	–.00	.03	1.00	
F4 Acceptance of evolution: the theory is (not) scientific	.00	.11	.01	1.00
Knowledge of human evolution	–.11	.23**	.03	.36**

** $p < .01$ **Table 5***Comparison of Correlations in the Online Group with Correlations in the In-Class Group*

Components obtained in PCA	$Z_{\text{difference}}$	p
	Knowledge of human evolution	
Religiosity (F1)	–19.51	< .001
Acceptance of evolution: the theory (F2)	–35.26	< .001
Attitudes toward biology (F3)	–25.97	< .001
Acceptance of evolution: the theory is (not) scientific (F4)	11.85	< .001
Religiosity (F1)		
Acceptance of evolution: the theory (F2)	13.45	< .001
Attitudes toward biology (F3)	–0.39	.37
Acceptance of evolution: the theory is (not) scientific (F4)	–4.98	< .001
Acceptance of evolution: the theory (F2)		
Attitudes toward biology (F3)	10.11	< .001
Acceptance of evolution: the theory is (not) scientific (F4)	22.52	< .001
Attitudes toward biology (F3)		
Acceptance of evolution: the theory is (not) scientific (F4)	0.83	.28

Discussion

Students' Knowledge of Human Evolution

The first research question dealt with whether students' knowledge of human evolution was impacted by online education. Students' knowledge of human evolution was tested by 14 items. In line with the curriculum (Učni načrt, 2011), one group learned about this topic during the lockdown in the 2020/21 school year, and the other group learned about it a year later (2021/22) in regular in-school classes. Overall, their knowledge of human evolution ranged from very good ($M = 4.56$) to average ($M = 2.58$) on a 5-point Likert scale. Students' knowledge was satisfactory considering that no item was answered correctly below average. During the lockdown, students' motivation and well-being, as perceived by parents, decreased (Hornstra et al., 2022). As a consequence, it was expected that students learning online would show lower academic achievements than students learning in class (Fiedler et al., 2022). However, contrary to the expectations, the performance of students in the online group did not significantly differ from the students in the in-class group ($ps < .05$). The participants in both groups were taken from the same four secondary schools and presumably had relatively similar general academic abilities. Most of the students from these schools are continuing their education at the university level.

The reason that both student groups performed similarly could lie in the fact that effective learning requires an

actively involved student as opposed to transmission of information. A study by Buchan et al. (2020) indicated that in teaching there is more than one successful method that leads to effective engagement and hence to knowledge.

Despite these results, it can probably not be presumed that online education is as effective as in-class education. This is especially because teachers were also not adequately prepared for alternative teaching methods using digital technologies that include augmented reality, virtual reality, and computer games (Yu, 2022). However, the impact of lockdown was found to be advantageous for high achievers (Samsen-Bronsveld et al., 2023).

A limitation was that the knowledge of pre-lockdown years of students could not be compared with the knowledge of students in this study. Therefore, it is possible that neither group gained knowledge: the group educated online did not acquire it because of inadequate teaching and learning practices. In contrast, the group educated in-class did not acquire it as a consequence of less strict rules that applied during the lockdown. Barton (2023) found that during the lockdown schools were inclined to be more patient and lenient with students, and standards were often lowered. A survey in the United States showed that primary and secondary school students were several months behind schedule due to the pandemic. This effect might be visible in schools at higher levels of education in the following years, when these students entered them (Dorn et al., 2021; Steyn et al., 2023).

There are also other factors beside biology classes that may have contributed to the results of this study, such as popular media (Modell et al., 2005), digital and print media (Garibi et al., 2021), or students' social surroundings.

Influence of Students' Gender and Level of Parents' Education on Knowledge of Human Evolution

The second research question dealt with whether students' knowledge of human evolution was influenced by their gender and the level of parents' education. There are strong indications that one important factor that positively influences the understanding of basic evolutionary concepts is a higher level of parental education (Salazar-Enriquez et al., 2023). This is in line with the last PISA report (Šterman Ivančič & Mlekuž, 2023), which found that socioeconomic status is an important predictor of students' achievements in mathematical literacy. The results of past PISA data collections show that students that report coming from weaker socioeconomic backgrounds often also report that their parents had lower levels of education and have less-valued occupations, and on average, these students achieved lower results on the PISA test (OECD, 2016; OECD, 2017). Contrary to expectations, in this study, there was no significant impact of maternal education on knowledge of human evolution, and only a minor positive impact of higher paternal education.

Between females and males, there were six (out of 14) significant but mostly negligible differences in knowledge of evolution. On all six items, girls performed worse than boys. This could be explained by the suggestion that females' acceptance of evolution is mostly lower, which may be a consequence of religiosity, which is generally higher in females (Fiedler et al., 2024; Stahi-Hitin & Yarden, 2022). However, this explanation might not be relevant for Slovenia as a more secular country (Kuschmierz et al., 2020; Miller, 2006). Moreover, the relationship between knowledge of evolution and acceptance of evolution is inconsistent (e.g., Beniermann et al., 2020; Salazar-Enriquez et al., 2023).

Correlations between Students' Knowledge of Human Evolution and Contextual Factors

The third research question dealt with whether there is a correlation between students' knowledge and selected contextual factors; that is, the four components that were extracted in PCA. These were religiosity (F1), acceptance of evolution: the theory (F2), attitudes toward biology (F3), and acceptance of evolution: the theory is (not) scientific (F4). Unexpectedly, no significant correlations were found among these four components in the group that learned in class, and none in the group with online education. However, there were significant positive correlations between knowledge of evolution and three of these components (F2, F3, F4), but none with religiosity (F1). According to most studies, knowledge and acceptance of evolution are positively correlated (Carter et al., 2015; Salazar-Enriquez et al., 2023; Tavares & Bobrowski, 2018; Torkar & Šorgo, 2020), although some other studies have indicated that this relationship is not strong (Beniermann, 2019; Mead et al., 2017).

Most research (e.g., Ha et al., 2019; Salazar-Enriquez et al., 2023; Šorgo et al., 2014) has found that knowledge and acceptance of evolution are negatively correlated with religious beliefs. People that have cognitive biases, such as essentialism or teleological thinking, are not inclined toward biological evolution (Berti et al., 2017). However, some recent studies support a different view: namely, that understanding evolution and acceptance of evolution might not be highly influenced by religious affiliation and religiosity (Benierman et al., 2020). The relationship between religious faith and acceptance of evolution can have several forms (Ha et al., 2019). Evidence has been

found for other, nonreligious factors that may account for it. Among these factors are sociocultural factors, the level of knowledge of evolution (da Silva Oliveira et al., 2022), age, the time since students had first heard of evolution (Mpeta et al., 2015), and gender (Fiedler et al., 2024).

In this study, the group educated online differed significantly in most correlations from the group with regular in-school education. Only two correlations were not different: between attitudes toward biology (F3) and religiosity (F1), and between attitudes toward biology (F3) and acceptance of evolution (F4). It is surprising that the online group did not differ from the in-class group in the correlation between attitudes toward biology (F3) and acceptance of evolution (F4). According to research, attitudes toward biology are strongly influenced by teachers' personality, their teaching strategies (Kubiato et al., 2017; Prokop et al., 2007), and students' effort invested in learning (Hansen & Birol, 2014). All of these factors were affected by online teaching. These results also contradict findings by Mantelas and Mavrikaki (2020) that acceptance of evolution could be significantly influenced by attending an evolutionary biology course.

Conclusions and Implications

A large body of research in recent years has addressed the consequences of online education during the COVID-19 pandemic. This study explored the impact of online education on students' knowledge. During the lockdown, students learned about several topics, one of which was human evolution, which is a relatively independent and separate subject matter in the Slovenian curriculum. Therefore, human evolution was chosen as the topic for testing the impact of online education on knowledge.

The first finding of this study was that, contrary to expectations, there were no differences in knowledge of human evolution. It remains unclear why students that were educated online performed equally well as those educated in-class. It seems that this finding indicates the importance of broader social and psychological factors. A follow-up qualitative study using a semi-structured interview could explore factors that were not taken into consideration in this study to better understand the impact of the lockdown and explore the underlying reasons, which would be helpful in future interventions.

The second finding concerned the impact of gender and the level of parental education: boys had better knowledge of human evolution than girls did; there was no impact of maternal education, and a positive impact of higher paternal education. The third finding concerned correlation between students' knowledge and acceptance of evolutionary concepts, their attitudes toward biology, and religiosity. It was confirmed that in Slovenia religiosity is not an obstacle to learning about human evolution and accepting evolutionary concepts. However, knowledge of human evolution was positively associated with attitudes toward biology and acceptance of evolution. The second and the third findings indicate the importance of background factors that had stronger impact on the knowledge than the online education did. They are partially out of the scope of a school; however, they could be addressed at the level of the curriculum and through the teachers.

One limitation of this study is that the sample of upper-secondary school students consisted mostly of urban high-achieving students. Therefore, the results of this study cannot be generalized to other parts of the country or to students at other academic levels. An additional limitation is the instrument used to gather data about knowledge of human evolution, which had a relatively low reliability. In future, additional items or other instruments could be used. Another limitation is that, due to its cross-sectional nature, this study could not evaluate whether these findings are long lasting. Therefore, the same knowledge should be tested on years of students that still feel the consequences of online education in 2019/20 and 2020/21.

Declaration of Interest

The authors declare no competing interest.

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